TECHNICAL SUPPORT DOCUMENT FOR QUANTIFICATION OF AGRICULTURAL BEST MANAGEMENT PRACTICES

FINAL

Prepared for:

Arizona Department of Environmental Quality
3033 N. Central Avenue
Phoenix, Arizona 85012-2809

Prepared by:

URS Corporation
2870 Gateway Oaks Dr., Suite 300
Sacramento, California 95833

and

Eastern Research Group, Inc.
8950 Cal Center Dr., Suite 260
Sacramento, California 95826-3259

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ACRONYMS

A	acres
A.A.R.	Arizona Administrative Register
A.R.S.	Arizona Revised Statutes
ADEQ	Arizona Department of Environmental Quality
AP	acre-passes
AP-42	U.S. Environmental Protection Agency Document ACompilation of Air Pollutant Emission Factors@
ARB	Air Resources Board, State of California
BMPs	best management practices
C	climatic factor
comp	composition of soil
EET	emission estimating technique
EF	emission factor
F	fraction of Maricopa County that lies within the PM_{10} non-attainment area
k	particle size multiplier
K	surface roughness factor
LN	unsheltered field width factor

lbs	pounds
lbs/day	pounds per day
mph	miles per hour
NAAQS	National Ambient Air Quality Standard
NO_x	nitrogen oxides
NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter of 10 microns or less
primfml	prime farmland classification
s	soil silt content
SCAQMD	South Coast Air Quality Management District
SSURGO	Soil Survey Geographic (Database)
TSD	technical support document
U.S. EPA	U.S. Environmental Protection Agency
VN	vegetative cover factor
VMT	vehicle miles traveled

1.0 INTRODUCTION

On June 10, 1996, the U.S. Environmental Protection Agency (U.S. EPA) designated a portion of Maricopa County, Arizona, as a serious non-attainment area for particulate matter less than or equal to 10 micrometers in diameter (PM_{10}). The Maricopa County PM_{10} Non-Attainment Area comprises approximately 2,880 square miles of Maricopa County (see Figure 1-1). Some of the previously unregulated sources that need to be addressed in future control plans for PM_{10} include unpaved roads, unpaved parking lots, vacant lots, and agriculture.

In two previous studies, the Arizona Department of Environmental Quality (ADEQ) examined the sources contributing to exceedences of the 24-hour PM_{10} National Ambient Air Quality Standard (NAAQS) (ADEQ 1997; ADEQ 1999). ADEQ=s analyses included examination of monitoring data, estimating emissions based on micro-scale field studies, and modeling of a design day (i.e., April 9, 1995). The ADEQ studies help to form the basis for development of control strategies for the entire non-attainment area.

This technical support document (TSD) supports ADEQ=s previous work by assessing the emissions from agricultural practices and the impacts of agricultural best management practices (BMPs) for the Maricopa County PM_{10} Non-Attainment Area. The focus is on agricultural emissions and implementation of BMPs for the April 1995 design day. The following agricultural emission sources were examined:

$ Tillage and harvest: Any mechanical practice that disturbs cropland or crops on a commercial farm.

- Non-cropland: Any commercial farm land that:
  - Is no longer used for agricultural production,
  - Is no longer suitable for production of crops,
  - Is subject to a restrictive easement or contract that prohibits use for the production of crops, or
  - Includes a private farm road, ditch bank, equipment yard, storage yard, or well head.

Figure 1-1

$ Cropland: Land on a commercial farm that:
  - C Is within the time frame of final harvest to plant emergence,
  - C Has been tilled in a prior year and is suitable for crop production, but is currently fallow, or
  - C Is a turn-row.

The BMPs, determined through extensive work by ADEQ, the Governor=s Agricultural BMP Committee, and other stakeholders, are summarized in Table 1-1. The BMP regulatory background, developmental process, and implementation guidelines are documented in the draft document entitled A*Guide to Agricultural PM_{10} Best Management Practices*, *Maricopa County, Arizona PM_{10} Non-Attainment Area*@ (GABMPC, 2000).

Section 2.0 of this TSD includes a description of the methodology used to assess the BMPs and quantify their impact on emissions from agricultural practices. Section 3.0 describes the methodology and results for the April 1995 design day emissions estimates. Section 4.0 describes the methodology and results for the projected 2006 design day emissions estimates. References are listed in Section 5.0, and Appendices A through E contain copies of literature search records, detailed calculations, telephone contact records, and the survey of farmers to obtain information on non-cropland areas and activity.

Table 1-1. Summary of Agricultural Best Management Practices for the Maricopa County PM_{10} Non-Attainment Area

Tillage and Harvest	Non-Cropland	Cropland
Chemical irrigation	Access restriction	Artificial wind barrier
Combining tractor operations	Aggregate cover	Cover crop
Equipment modification	Artificial wind barrier	Cross-wind ridges
Limited activity during a high wind event	Critical area planting	Cross-wind strip-cropping
Multi-year crop	Manure application	Cross-wind vegetative strips
Planting based on soil moisture	Reduced vehicle speed	Manure application
Reduced harvest activity	Synthetic particulate suppressant	Mulching
Reduced tillage system	Track-out control system	Multi-year crop
Tillage based on soil moisture	Tree, shrub, or windbreak planting	Permanent cover
Timing of tillage operation	Watering	Planting based on soil moisture
		Residue management
		Sequential cropping
		Surface roughening
		Tree, shrub, or windbreak planting

2.0 ANALYSIS OF AGRICULTURAL BEST MANAGEMENT PRACTICES

In an effort to address agriculture=s contribution to PM_{10} non-attainment in Maricopa County, the Governor=s Agricultural Best Management Practices Committee was created by law in 1998 (Arizona Revised Statutes [A.R.S.] '49-457). The Committee identified BMPs that focus on feasible, effective, and common sense practices while minimizing negative impacts on local agriculture (GABMPC, 2000). The remainder of this section describes these BMPs, ranks them based on their likelihood for implementation, summarizes relevant control efficiency data, and proposes an implementation scenario for purposes of estimating emission reductions achievable through BMP implementation.

2.1 Description of Best Management Practices

The BMPs, as described below for purposes of this TSD, are aimed at reducing PM_{10} for each of the three agricultural emissions source categories: Tillage and Harvest, Non-Cropland, and Cropland.

Tillage and Harvest BMPs:

$ Chemical irrigation: Applying a fertilizer, pesticide, or other agricultural chemical in an irrigation water system to reduce the number of passes across a field with tractors, sprayers, fertilizer applicators, and other mechanized equipment.

$ Combining tractor operations: Performing two or more tillage, cultivation, planting, or harvesting operations with a single tractor or harvester pass to reduce the number of passes or trips that a tractor, implement, harvester, or other farming support vehicle makes across a field or unpaved surface.

$ Equipment modification: Modifying agricultural equipment to prevent or reduce particulate matter suspension during operation of equipment on cropland.

$ Limited activity during a high wind event: Eliminating tillage and soil preparation activities when the measured wind speed at 6 feet in height is above 25mph at the commercial farm site.

$ Multi-year crop: Growing a crop, pasture, or orchard on a continuous basis for more than one year thus providing surface covers, such as crops, pasture, and orchards, and protecting the soil surface from erosive winds.

$ Planting based on soil moisture: Applying water to soil before performing planting operations.

$ Reduced harvest activity: Reducing the number of harvest passes using mechanized cutting and removal of crops from fields.

$ Reduced tillage system: Reducing the number of tillage operations used to produce a crop.

$ Tillage based on soil moisture: Applying water to the soil before or during tillage, or delaying tillage to coincide with precipitation.

$ Timing of tillage operation: Performing tillage operations at a time that will minimize the soil=s susceptibility to generate PM_{10}.

Non-Cropland BMPs:

$ Access restriction: Restricting or eliminating public access to non-cropland with signs or physical obstruction.

$ Aggregate cover: Applying gravel, concrete, recycled road base, caliche, or other similar material to unpaved farm roads, parking areas, and canal banks to help reduce the amount of erodable soil particles exposed to the surface.

$ Artificial wind barrier: A physical barrier to the wind that disrupts the erosive flow of wind over unprotected areas.

$ Critical area planting: Using trees, shrubs, vines, grasses, or other vegetative cover to control soil movement and protect the soil surface from wind erosion when adequate cover does not exist.

$ Manure application: Applying animal waste or biosolids to a soil surface to maintain or improve chemical and biological condition and reducing wind erosion and associated PM_{10} emissions.

- $ Reduced vehicle speed: Operating farm vehicles or farm equipment on unpaved private farm roads at speeds not to exceed 20 mph.

- $ Synthetic particulate suppressant: Applying a product such as lignosulfate, calcium chloride, magnesium chloride, an emulsion of a petroleum product, an enzyme product, and polyacrylamides to unprotected areas, such as unpaved roads, right-of-ways, and abandoned fields.

- $ Track-out control system: A device to remove mud or soil from a vehicle before the vehicle enters a paved public road.

- $ Tree, shrub, or windbreak planting: Providing woody vegetative barrier to the wind. Barriers perpendicular to the wind direction can reduce wind speeds by changing the pattern of airflow over the land surface helping to reduce wind erosion and PM_{10} emissions.

- $ Watering: Applying water to non-cropland bare soil surfaces such as unpaved roadways and equipment yards where high traffic areas exist.

Cropland BMPs:

- $ Artificial wind barrier: A physical barrier to the wind, such as solid board fences, burlap fences, crate walls, or bales of hay.

- $ Cover crop: Plants or a green manure crop grown for seasonal soil protection or soil improvement.

- $ Cross-wind ridges: Forming soil ridges during a tillage operation that can disrupt the erosive forces of high winds.

- $ Cross-wind strip cropping: Planting strips of alternating crops within the same field, or managing residue cover in strips that are established across the prevailing wind direction for a particular wind erosion period.

- $ Cross-wind vegetative strips: Planting herbaceous cover in one or more strips within the same field to create a protective windbreak that disrupts the erosive forces of high winds.

- $ Manure application: Applying animal waste or biosolids to a soil surface to maintain or improve chemical and biological condition of the soil and help to reduce wind erosion.

- $ Mulching: Applying plant residue or other material that is not produced onsite to a soil surface thus adding a protective layer to the soil surface to reduce soil movement by high wind events.

- $ Multi-year crop: Growing a crop, pasture, or orchard on a continuous basis for more than one year to protect the soil surface from erosive winds.
- $ Permanent cover: Maintaining a long-term (perennial) vegetative cover on agricultural land that is temporarily not producing a major crop.

- $ Planting based on soil moisture: Applying water to soil before performing planting operations thus reducing particulate matter from being generated during the planting operation.

- $ Residual management: Managing the amount and distribution of crop and other plant residues on a soil surface thus helping to reduce wind erosion and the generation of PM_{10} emissions.

- $ Sequential cropping: Growing crops in a sequence that minimizes the amount of time bare soil is exposed on a field thus helping reduce the window of time that cropland is susceptible to PM_{10} generation.

- $ Surface roughening: Manipulating a soil surface to produce or maintain clods that help disrupt the erosive force of the wind over an unprotected soil surface.

- $ Tree, shrub, or windbreak planting: Providing a woody vegetative barrier to the wind.

2.2 Determination of Best Management Practices Impacts

The Arizona Administrative Register (A.A.R), Title 18, Chapter 2, '609-611 contains the rulemaking for the AAgricultural PM_{10} General Permit.@ The General Permit requires that any agricultural operation greater than 10 contiguous acres and located within the Maricopa County PM_{10}

Non-Attainment Area must implement at least one BMP from each of the following categories: Tillage and Harvest, Non-Cropland, and Cropland. (The rule is not applicable to farms located on tribal lands.) Virtually all (i.e., 99.8%) of the farms that operated in Maricopa County during 1995 were 10 acres or larger (USDA, 1999).

In order to quantify the emission reductions achievable from implementation of the General Permit, the following steps were followed:

1. The applicability of each BMP to each major crop grown in Maricopa County (i.e., cotton, wheat, barley, corn, alfalfa and other hay, vegetables, and citrus) was determined.

2. The BMPs were ranked based on the likelihood that they would be implemented by a farmer.

3. Control efficiencies (i.e., percentage reduction achievable) were determined through a literature search and by independent calculations, as necessary.

4. An implementation scenario was developed based on the BMPs most likely to be implemented.

Applicability of BMPs by crop type. The applicability of the BMPs by crop type was identified by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) (Schmidt, 2000). Some factors impacting BMP applicability include technical feasibility and crop switching (e.g., a farmer switching between cotton and small grain might employ different BMPs in different years). Table 2-1 shows the applicability of each BMP by crop type for crops grown in Maricopa County.

Ranking of BMPs. Members of the agricultural community were asked to rank each BMP within each category on a scale from 1 to 10 from most-likely to least-likely to be implemented. Some factors impacting the likelihood of implementation are economic feasibility and the ability to achieve the greatest amount of PM_{10} reduction. Also, an important factor that would impact a farmer's decision to implement specific BMPs is whether or not they own their land. A farmer who leases land is less likely to implement a permanent BMP, such as artificial wind barriers, than a farmer who owns land. The potential significance of this factor is demonstrated by the fact that in 1997, approximately 70% of farmland acreage in Maricopa County was operated by a part owner or tenant, versus approximately 30% of land that was operated by an owner (USDA, 1999).

Control efficiency determination. Relevant documents obtained from ADEQ, NRCS, and other sources (e.g., U.S. EPA guidance documents) were reviewed and control efficiencies applicable to the subject BMPs were recorded. When no control efficiency information could be found in the literature for the BMPs with a ranking of A1@ (most likely to be implemented), additional research and/or calculations were performed in order to quantify a control efficiency, or range of control efficiency, of the specific BMP. An exception to this is that no data were found in the literature pertaining to control efficiency for two BMPs ranked A1@: chemical irrigation and manure application; thus, these BMPs could not be included in the implementation scenario described below. Table 2-2 shows the ranking and summarizes the

Table 2-1. Applicability of Agricultural Best Management Practices

BMP		Applicable Crop						
Category	**Action**	**Cotton**	**Wheat**	**Barley**	**Corn**	**Alfalfa/ Other Hay**	**Vegetables**	**Citrus**
Tillage and Harvest	Chemical irrigation	T			T			
	Combining tractor operations	T	T	T	T		T	T
	Equipment modification	T	T	T	T	T		
	Limited activity during a high-wind event	T	T	T	T	T	T	T
	Multi-year crop	T	T	T	T			
	Planting based on soil moisture	T	T	T	T		T	
	Reduced harvest activity	T				T		
	Reduced tillage system	T	T	T	T			
	Tillage based on soil moisture		T	T	T			
	Timing of tillage operation	T	T	T	T			
Non-Cropland	Access restriction	T	T	T	T	T	T	T
	Aggregate cover	T	T	T	T	T	T	T
	Artificial wind barrier	T	T	T	T	T	T	T

BMP		Applicable Crop						
	Critical area planting	T	T	T	T	T	T	T

BMP		Applicable Crop						
	Manure application	T	T	T	T	T	T	T
	Reduced vehicle speed	T	T	T	T	T	T	T
	Synthetic particulate suppressant	T	T	T	T	T	T	T
	Track-out control system	T	T	T	T	T	T	T
Non-Cropland (Cont.)	Tree, shrub, or windbreak planting	T	T	T	T	T	T	T
	Watering	T	T	T	T	T	T	T
Cropland	Artificial wind barrier					T	T	T
	Cover crop	T	T	T	T		T	T
	Cross-wind ridges	T	T	T	T		T	
	Cross-wind strip cropping		T	T	T	T	T	
	Cross-wind vegetative strips	T	T	T	T		T	
	Manure application	T	T	T	T			
	Mulching	T						T
	Multi-year crop	T	T	T	T			
	Permanent cover[a]							
	Planting based on soil moisture	T	T	T	T		T	

BMP	Applicable Crop						
Residue management	T	T	T	T			

BMP		Applicable Crop						
	Sequential cropping	T	T	T	T		T	
	Surface roughening	T	T	T	T		T	
	Tree, shrub, or windbreak planting	T	T	T	T	T	T	T

Notes:[a] This BMP applies to fallow land.

Table 2-2. Ranking and Summary of Control Efficiencies for Agricultural Best Management Practices

BMP			Control Efficiency		Comments
Category	Action	Ranking	PM_{10} Control Efficiency	Reference	
Tillage and Harvest	Chemical irrigation	1-4	N/A	N/A	No data could be found in the literature to support a control efficiency estimate; however, the control efficiency associated with eliminating acre-passes through applying chemicals during irrigation is probably relatively small compared to other BMP control efficiencies.
	Combining tractor operations	1	35-50%	Coates, 1994	This study identified total PM_{10} emissions generated for five different cotton tillage systems, including conventional tilling. Four of the systems combine several tillage operations (e.g., shredding, disking, mulching). Emission reductions of from 35% to 50% compared to conventional tilling are possible.
	Equipment modification	3-5	50%	MRI, 1981	Control efficiency is for electrostatically charged fine-mist water spray.
	Limited activity during a high-wind event	1-3	69.8%	Sierra, 1997	Control efficiency is based on reduction in emissions when no tilling occurs at wind speeds exceeding 10 mph. Methodology for calculating control efficiency based on AP-42 Section 13.2.4 (aggregate handling and storage piles).
			1-5%	SCAQMD, 1997	Control efficiency assumes no tilling when wind speed exceeds 25 mph. SCAQMD used 3% in their emission reduction calculations.
			25%	(Calculated)	Control efficiency was calculated based on 0 tillage emissions during hours on 4/9/95 when wind speed exceeded 25 mph. See Appendix B for details.
	Multi-year crop	1	66-100%	(Calculated)	Control efficiency was based on the assumption that alfalfa (3 to 5

BMP			Control Efficiency		Comments
					years per planting) could replace cotton, wheat, barley, and corn, which require annual planting. Emission reductions would be from 66% (i.e., 2 out of 3 years with no tilling) to 100% (i.e., full-time ground cover) for tillage and wind erosion control, respectively. See Appendix B for details.
Tillage and Harvest (Cont.)	Planting based on soil moisture	1	30%	(Calculated)	No data could be found in the literature that was directly related to the control efficiency for this BMP; however, it is reasonable to expect that the effect of the BMP would be at least as great as the reduction of wind erosion emission that ARB predicts if the effect of irrigation were considered within the predictive wind erosion equation (ARB, 1997; Francis 2000).
	Reduced harvest activity	1	29-71%	(Calculated)	Control efficiency was calculated based on a range of assumed reductions in the number of acre-passes during harvest operations. See Appendix B for details.
	Reduced tillage system	4	35-50%	Coates, 1994	(See comment above for ACombined tractor operations.@
			60%	MRI, 1981	Control efficiency is for a Alow energy system@ (i.e., minimum tillage technique) that confines farm equipment and vehicle traffic to specific areas (for cotton and tomatoes).
			25-100%	MRI, 1981; U.S. EPA, 1992	Control efficiency is for application of herbicide which reduces need for cultivation (i.e., 25% for barley, alfalfa, and wheat; 100% for cotton, corn, tomatoes, and lettuce).
			30%	MRI, 1981; U.S. EPA, 1992	Control efficiency is for laser-directed land plane which reduces the amount of land planing.
			50%	MRI, 1981; U.S. EPA, 1992	Control efficiency is for using Apunch@ planter instead of harrowing (for cotton, corn, and lettuce).
			50%	MRI, 1981	Control efficiency is for using Aplug@ planting that places plants more exactly and eliminates the need for thinning (for tomatoes,

BMP			Control Efficiency		Comments
					only).
			100%	MRI, 1981	Control efficiency is achieved by fall listing of tomato acreage which eliminates the need for spring harrowing and rolling.
Tillage and Harvest (Cont.)	Reduced tillage system (Cont.)		50%	MRI, 1981; U.S. EPA, 1992	Control efficiency is for aerial seeding which produces less dust than ground planting (for alfalfa and wheat).
		4	91-99.5%	Grantz et al, 1998a	Control efficiency is for revegetation of fallow agricultural lands by direct seeding.
	Tillage based on soil moisture	2	90%	MRI, 1981; U.S. EPA, 1992	Control efficiency is for sprinkler irrigation as a fugitive dust control measure. Also, sprinkler irrigation could reduce the need for extensive land planing associated with surface irrigation.
	Timing of tillage operation	1	50-60%	(Calculated)	Control efficiency was calculated based on a range of assumed reductions in surface roughness factors (i.e., AK@ in the AP-42 emission factor for estimating wind erosion emissions). See Appendix B for details.
Non-Cropland	Access restriction	1	Variable	U.S. EPA, 1992	Control efficiency is proportional to the percent reduction of VMT.
			0-3%	(Calculated)	Control efficiency was calculated by assuming a range of reduction in public VMT (i.e., up to 3% of total VMT is from unauthorized public travel on agricultural unpaved roads).
	Aggregate cover	3	Variable	U.S. EPA, 1988	Control efficiency is proportional to the percent reduction of silt content.
	Artificial wind barrier	10	0-90%	U.S. EPA, 1992	Control efficiency assumes a 50% porosity fence.
			54-71%	Grantz et al, 1998b	Control efficiency is for a wind fence.
			4.3-32.5%	Bilbro and Stout, 1999	Control efficiency based upon reduction in wind velocity by a wind fence made from plastic pipe with a range of optical density of from 12% to 75%.

BMP			Control Efficiency		Comments
	Critical area planting	5	N/A	N/A	No data could be found in the literature on which to base a control efficiency estimate.

BMP			Control Efficiency		Comments
Non-cropland (Cont.)	Manure application	1	N/A	N/A	No data could be found in the literature on which to base a control efficiency estimate.
	Reduced vehicle speed	1	Variable	U.S. EPA, 1992	Control efficiency is proportional to the percent reduction of vehicle speed because of linear relationship between vehicle speed and emissions.
			55-61%	Flocchini, Cahill, and Matsumura, 1994	Control efficiency is based on reduction in vehicle speeds from 25 mph to 10 mph.
			7-77%	Flocchini, Cahill, and Matsumura, 1994	Control efficiency is based on reduction in vehicle speeds from 25 mph to 15 mph.
	Synthetic particulate suppressant	7	60-90%	U.S. EPA, 1992	Control efficiency assumes application (i.e., ground inventory) $0.05 gallon/yard^2.
			47-99%	Flocchini, Cahill, and Matsumura, 1994	Control efficiency is based on application of either lignin sulfanate, magnesium chloride, or oil.
			75%	SCAQMD, 1997; Sierra, 1997; SCAQMD, 1994	Control efficiency is based on chemical stabilization of industrial haul roads.
	Track-out control system	5-7	85-95%	SCAQMD, 1997; Sierra, 1997; SCAQMD, 1994	Control efficiency range is for different types of controls including: paving, chemical stabilization, installation of truck washers, and street cleaning.
	Tree, shrub, or windbreak planting	9	25%	Sierra, 1997	Control efficiency is for trees.

BMP			Control Efficiency		Comments
Non-cropland (Cont.)	Watering	3	81-93%	U.S. EPA, 1992	One day reduction only.
			50%	SCAQMD, 1997	
Cropland	Artificial wind barrier	10	0-90%	U.S. EPA, 1992	Assumes a 50% porosity fence.
			54-71%	Grantz et al, 1998b	Control efficiency is for a wind fence.
			4.3-32.5%	Bilbro and Stout, 1999	Control efficiency based upon reduction in wind velocity by a wind fence made from plastic pipe with a range of optical density of from 12% to 75%.
	Cover crop	4	20-66%	Papendick and Veseth, 1996	
	Cross-wind ridges	3	24-93%	Grantz et al, 1998b	Control efficiency is for furrows.
			20-80%	Papendick and Veseth, 1996	
	Cross-wind strip-cropping	10	N/A	N/A	
	Cross-wind vegetative strips	10	N/A	N/A	
	Manure application	3	N/A	N/A	No data could be found in the literature on which to base a control efficiency estimate.
	Mulching	10	50-55%	Papendick and Veseth, 1996	Control efficiency is for straw.
Cropland (Cont.)	Multi-year crop	1	66-100%	(Calculated)	Calculated control efficiency based on assumption that alfalfa will replace cotton, wheat, barley, and corn. See comment under ATillage and Harvest,@ above, and Appendix B for details.

BMP			Control Efficiency		Comments
	Permanent cover	8	25-75%	SCAQMD, 1997	Control efficiency is for vegetative cover on fallow agricultural lands.

BMP			Control Efficiency		Comments
			50%	Sierra, 1997	Control efficiency is for grass revegetation of fallow fields
		8	60%	Sierra, 1997	Control efficiency is for revegetation of open areas or vacant parcels > 10 acres.
	Planting based on soil moisture	2	30%	(Calculated)	Based on ARB research into the effect of irrigation on wind erosion. See comment under ATillage and Harvest,@ above.
	Residue management	1	39-92%	(Calculated)	Control efficiency was calculated based on a range of assumed residue surface covers. Methodology from Papendick and Veseth, 1996. See Appendix B for details.
	Sequential cropping	5	50%	MRI, 1981	Control efficiency for double cropping corn and wheat.
	Surface roughening	2	15-64%	Grantz et al, 1998a	Control efficiency for increasing surface roughness using rocks and soil aggregates.
			75%	Papendick and Veseth, 1996	Control efficiency for frozen ripping/surface roughening.
	Tree, shrub, or windbreak planting	9	25%	Sierra, 1997	Control efficiency is for trees.

Notes:
AP-42 = U.S. Environmental Protection Agency=s ACompilation of Air Pollutant Emission Factors.@
ARB = State of California, Air Resources Board
K = surface roughness factor.
mph = miles per hour.
N/A = Not available.
PM_{10} = particulate matter equal to or less than 10 microns in aerodynamic diameter.
SCAQMD = South Coast Air Quality Management District.
VMT = vehicle miles traveled.

information obtained from the literature search, and the subsequent analysis conducted to determine control efficiency information for the BMPs most likely to be implemented.

Implementation scenario. The implementation scenario establishes a basis for estimating the emission reductions expected to be achieved through compliance with the General Permit. Since a farmer can select from a list of BMPs for each category, it cannot be determined with certainty which specific BMPs will actually be implemented. However, knowing the most likely BMPs to be implemented (i.e., ranked A1@) and the control efficiency or range of control efficiencies associated with each of those BMPs, the percentage of emission reduction can be estimated.

Table 2-3 summarizes the implementation scenario selected for this analysis that includes all the BMPs having a ranking of A1@ for which a control efficiency can be determined. The implementation scenario assumes that any farmer will implement only one BMP from each category. The net control efficiencies are the product of the (maximum, minimum, and mid-point) control efficiency, the compliance factor, and the relevancy factor for each BMP by crop type. These net control efficiencies are used in the calculation of projected emissions for 2006 and the overall emissions reductions. (See Section 4.0 of the TSD).

The assumed compliance factor for each BMP is 80% (i.e., the product of the U.S. EPA default compliance rate of 80% and the estimated percentage of cropland within the non-attainment area that is on farms at least 10 acres in size [99.8%]). Relevancy factors are the estimate of the percentage of all farmers (or acreage), by crop, that are expected to implement a given BMP. For example, it is assumed that emissions attributable to tillage of cotton acreage will be controlled by

ACombining Tractor Operations@ (23%), ALimited Activity During High Wind Events@ (47%), and AMulti-Year Crops@ (30%). These estimates were determined first by estimating the relevancy of the multi-year crop BMP. Based on information provided by Maricopa County farmers, and analysis of crop data statistics (ADOA, 2000), it was determined that the cotton, wheat, barley, and corn acreage in Maricopa County decreased by an annual rate of approximately 8% between 1995 and 1999. Furthermore, it was determined that this decrease was attributable to land going out of production (approximately 4% per year), switching to alfalfa (approximately 3% per year), and other factors.

Table 2-3. Scenario for Implementation of the Agricultural PM_{10} General Permit in the Maricopa County PM_{10} Non-Attainment Area

Summary			Net Control Efficiency by Applicable Crop[a] (%)						
Category	**BMP**		**Cotton**	**Wheat**	**Barley**	**Corn**	**Alfalfa/ Hay**	**Vegeta bles**	**Citrus**
Tillage	Combining Tractor Operations	Minimum	6.5	6.5	6.5	6.5	N/A	9.2	9.2
		Maximum	9.3	9.3	9.3	9.3		13.2	13.2
		Mid-Point	7.9	7.9	7.9	7.9		11.2	11.2
	Limited Activity During High-Wind Events	Minimum	-	-	-	-	-	-	-
		Maximum	-	-	-	-	-	-	-
		Mid-Point	9.3	9.3	9.3	9.3	20.0	13.2	13.2
	Multi-Year Crops	Minimum	-	-	-	-	N/A		
		Maximum	-	-	-	-			
		Mid-Point	15.8	15.8	15.8	15.8			
Harvest	Combining Tractor Operations	Minimum	14.0	27.9	27.9	27.9	N/A	27.9	27.9
		Maximum	20.0	39.9	39.9	39.9		39.9	39.9
		Mid-Point	17.0	33.9	33.9	33.9		33.9	33.9
	Reduced Harvest Activity	Minimum	11.6	N/A			23.1	N/A	
		Maximum	28.3				56.7		
		Mid-Point	20.0				39.9		
Non-Cropland	Access Restriction[b]	Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Summary		Net Control Efficiency by Applicable Crop[a] (%)							
		Mid-Point	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Summary			Net Control Efficiency by Applicable Crop[a] (%)						
	Reduced Vehicle Speed[b]	Minimum	2.8	2.8	2.8	2.8	2.8	2.8	2.8
		Maximum	30.7	30.7	30.7	30.7	30.7	30.7	30.7
		Mid-Point	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Cropland	Multi-Year Crops	Minimum	-	-	-	-	-	-	-
		Maximum	-	-	-	-	-	-	-
		Mid-Point	23.9	23.9	23.9	23.9	N/A		
	Residue Management	Minimum	7.3	11.0	11.0	7.3	N/A		
		Maximum	17.1	25.6	25.6	17.1			
		Mid-Point	12.2	18.3	18.3	12.2			
	Timing of Tilling Operations[c]	Minimum	9.3	14.0	14.0	9.3	N/A		
		Maximum	11.2	16.8	16.8	11.2			
		Mid-Point	10.2	15.4	15.4	10.2			
	Planting Based on Soil Moisture[c,d]	Minimum	-	-	-	-	-	-	-
		Maximum	-	-	-	-	-	-	-
		Mid-Point	5.6	N/A	N/A	5.6	N/A		

Notes:

[a] Net control efficiency is the product of the (minimum, maximum, mid-point) control efficiency, the compliance factor, and the relevancy factor. Compliance factor is the product of the percentage of cropland within the non-attainment area that is on farms at least 10 acres in size (99.8%), and the U.S. EPA default compliance rate (80%). Relevancy factor is the estimate of the percentage of all farmers that are expected to implement the BMP.

[b] Applies only to unpaved road travel.

[c] Agricultural PM_{10} General Permit Categorizes these as a tillage BMPs. For purposes of determining emission reductions, control efficiency was applied to cropland wind erosion emissions.

[d] This BMP is generally applicable to cotton, wheat, barley, corn, and vegetables throughout the year; however, for purposes of this analysis, the BMP is applied to only cotton and corn that are assumed to have been planted just prior to or during the design day of April 9.

N/A = Not applicable.
(-) = No basis for estimating maximum and minimum net control efficiency.

Based on this trend, the Arelevancy@ of the Multi-Year Crop BMP (i.e., replacing cotton, wheat, barley, and corn with 3-5 year alfalfa) was estimated as 30% for the period 1995 to 2006. Since the relevancy of the other applicable BMPs would total 70% (i.e., 100% - 30%), and ALimited Tilling on During High Wind Events@ is twice as likely to be implemented than ACombining Tractor Operations,@ the relevancy of these two BMPs would be 23% and 47%, respectively. Spreadsheets showing the relevancy factors for each BMP by crop are located in Appendix B.

3.0 AGRICULTURAL EMISSIONS FOR 1995

The basis for quantifying the impacts of the agricultural BMPs is a baseline PM_{10} emissions inventory of agricultural farmland and related activities. Since the BMPs are aimed primarily at addressing violations of the 24-hour PM_{10} NAAQS, it was necessary to estimate emissions on a daily basis. The specific Adesign-day@ selected for this analysis was April 9, 1995. This design-day is consistent with days selected for analysis in ADEQ=s Microscale Study (ADEQ, 1997; ADEQ, 1999) and the Maricopa Association of Governments (MAG=s) SIP and related documents (MAG, 2000).

The remainder of this section describes the methods and emission estimating techniques (EETs) used to estimate the design-day emissions, and the sources of data used in the EETs. Also, the results of the agricultural emissions inventory are presented and discussed.

3.1 Methodology

For purposes of using existing EETs, the agricultural emission categories were sub-divided into the following separate emission-generating activities:

$ Tillage;

$ Harvest;

$ Wind erosion of cropland;

$ Wind erosion of non-cropland (e.g., agricultural aprons and unpaved roads); and

$ Travel on unpaved agricultural roads.

Since the data used in application of these EETs were available only at the county- level for Maricopa County, it was necessary to adjust the EET equations for the fraction of Maricopa County farmland that lies within the PM_{10} non-attainment area. This factor, AF@, was determined to be 0.6276 (MAG, 2000).

3.1.1 Tillage

Tillage emissions for the 1995 design-day were estimated using the tillage emission factor equation in Section 9.1 of AP-42 (U.S. EPA, 1995). The tillage emission factor equation is in the following form:

where:

EF	=	tillage emission factor (lbs PM_{10}/acre-pass);
k	=	particle size multiplier (value of 0.15 for PM_{10}); and
s	=	soil silt content (percent).

An average soil silt content for agricultural land in Maricopa County was determined based on soil texture data that were obtained from the Soil Survey Geographic (SSURGO) Database located on the NRCS website (http://www.tw.nrcs.usda.gov). Detailed soil silt content data are presented in Appendix C. Only SSURGO tables for central Maricopa County (i.e., AZ651 tables) were used in the silt content calculations. The tables used consisted of Amapunit,@ Acomp,@ and Alayer.@ From the mapunit table, a Aprimfml@ (i.e., prime farmland classification) code greater than zero was used to select the map portions that had a relatively high probability of being agricultural land. The associated acreage was obtained from the comp table and the soil texture for each portion was obtained from the layer table. Only the first layer of soil data was used in this calculation.

Using the soil texture triangle and recommendations of NRCS staff, relevant silt contents were assigned by the soil texture classification. For example, if the soil texture was equal to

ASL@ (for sandy loam), a silt content of 30% was assigned (Camp, 2000). Finally, an average soil silt content of 35.2% for agricultural land was calculated based on the proportion of land with a given soil silt content. This value is considerably higher than the EPA default value of 18% which was used in the ADEQ Microscale Study (ADEQ, 1997; ADEQ, 1999).

Tillage emissions were then estimated by multiplying the calculated emission factor by the total number of crop-specific acre-passes related to tilling activities. The emissions equation is in the following form:

where:

$Tillage_{Crop}$ = tillage emissions for each crop type (lbs PM_{10});
EF = tillage emission factor (lbs PM_{10}/acre-pass);
AP_{Crop} = number of tillage acre-passes per acre for each crop type (acre-pass/acre);
A_{Crop} = total number of tilled acres for each crop type (acres);
AF = fraction of annual activity occurring on April 9; and
F = fraction of Maricopa County farmland within PM_{10} non-attainment area.

The annual number of tillage acre-passes per acre by crop type was obtained from the University of Arizona Cooperative Extension (Clay, 2000a). The crop-specific number of tilled acres in 1995 was obtained from Arizona Agricultural Statistics Report (ADOA, 2000). Daily emissions were estimated by crop type using estimates of tillage days per year (Clay, 2000b). The crop- and activity-specific periods were used to determine the fraction of tilling activity occurring on the April 9 design day.

The tilling activity over a given period was assumed to follow a normal distribution with activity levels peaking towards the middle of the period. Following this normal distribution, a tilling period can be divided into 5 segments: (i.e., 17%, 11%, 44%, 11%, and 17%) where each segment represents a percentage of the number of days in the period. The percentage of tilling activity occurring during each segment was assumed to be 10%, 20%, 40%, 20%, and 10%, respectively (Clay, 2000b). Table 3-1 gives an example how the tilling activity would be distributed for a tilling period occurring in March through May. Once the activity bins were determined, then the bin containing the April 9 design day was used to calculate the fraction of tilling activity on that day. In this example, the tilling activity on April 9 was calculated to be 1% of the total tilling activities.

Table 3-2 lists the crop-specific periods of activity that were used to determine the fractional activity on April 9. It should be noted that of the most frequently planted crops, only tillage of alfalfa was determined not to have occurred on the design day of April 9, 1995. Tilling activity for fall crops (e.g., fall lettuce, cantaloupe, and honeydew) were also assumed to be zero.

Table 3-1. Example Distribution of Tilling Activity for a March-May Period

Tilling Period	**Tilling Activity Completed During Period**	**March B May (92 days)**	**Percent Activity on April 9**
First 17%	10%	16 days: 3/1 to 3/16	Not relevant
Next 11%	20%	10 days: 3/17 to 3/27	Not relevant
Middle 44%	40%	40 days: 3/28 to 5/6	40%/40 days = 1%
One to last 11%	20%	10 days: 5/7 to 5/17	Not relevant
Last 11%	10%	16 days: 5/18 to 5/31	Not relevant

Table 3-2. Calendar of Tillage Operations by Crop

Operation	Cotton	Corn	Wheat	Barley	Alfalfa -stand establishment	Vegetables
Laser level	January-April	January-March			July-October	Generally planted in the fall and early-spring with corresponding tillage operations.
Plow (moldboard)					July-October	
Rip	January-April	January-March			July-October	
Disk	January-April	January-March	October-December	October-December	July-October	
Landplane	January-April	January-March				
Incorp. herb. (disk)	March-May	February-April				
List	March-May					
Mulch	February-April					
Plant	March-May	March-April/(Some double crop acreage planted in July)	November-January	November-January	September-October	
Buck rows	March-September					
Disk ends	September-December	July	April-June	April-June		
Cultivate	March-June	March-April				
Disk residue	October-January	July (Double crop - October)	May-July	May-July		
Make borders		February-April	October-January	October-January	August-October	

Note: Blanks indicate no operation was performed for the specified crop.
Source: Clay, 2000a.

3.1.2 Harvest

Harvest emissions were estimated using crop-specific emission factors for cotton (ARB, 1997), and wheat and barley (U.S. EPA, 1995). Emission factors are only available for these three crops grown in Maricopa County. The emission equation is in the following form:

where:

$Harvest_{Crop}$	=	harvest emissions for each crop type (lbs PM_{10}/year);
EF	=	harvest emission factor (lbs PM_{10}/acre/year);
A_{Crop}	=	total number of reported acres for each crop type (acre); and
F	=	fraction of Maricopa County farmland within PM_{10} non-attainment area.

As with the tillage EET, the number of harvested acres by crop was obtained from the Arizona Agricultural Statistics Report (ADOA, 2000). To convert the annual emissions to daily emissions, estimates of the number of harvest days per year for cotton, wheat, and barley were also obtained from the Agricultural Statistics Report (ADOA, 2000). However, based on this report, none of the three crops covered in this emission inventory were harvested in April. Therefore, the design-day PM_{10} emissions from crop harvesting were set equal to zero.

3.1.3 Wind Erosion

Wind erosion emissions were estimated for three different classes of agricultural land: cropland, non-cropland/unpaved roads, and non-cropland/other areas. The most commonly used wind erosion emission factor equation is based on a modified version of the soil erodibility equation developed by the U.S. Department of Agriculture (U.S. EPA, 1977) and is in the following form:

$$EF = 0.0125 \times I \times C \times K \times L' \times V'$$

where:

EF	=	PM_{10} emission factor (tons/acre/year);
0.0125	=	fraction of suspended particles that are PM_{10};
I	=	soil erodibility (tons/acre/year);
C	=	climatic factor (unitless);
K	=	surface roughness factor (unitless);
L′	=	unsheltered field width factor (unitless); and
V′	=	vegetative cover factor (unitless).

Similar to the method used to determine soil silt content, the erodibility factors for map components with primfml codes greater than zero (i.e., for agricultural land) were obtained from the layer table of the SSURGO database. An average soil erodibility was then calculated based on the portion of area associated with individual erodibility factors. As before, only central Maricopa County tables were used in this evaluation. The average erodibility factor obtained in this fashion was 65.4 tons/acre/year which compares favorably with the value of 63.6 tons/acre/year used in the ADEQ Microscale Study (ADEQ, 1997; ADEQ, 1999).

The climatic factor, "C," accounts for the effect of wind speed and soil moisture (precipitation and temperature) on wind erosion. An annual climatic factor of 0.318 was adapted from the Revised MAG 1999 Serious Area PM_{10} Plan (MAG, 2000). Other studies have indicated that the climatic factor can be lowered by as much as 30% if the effects of soil cloddiness (from irrigation) and the actual amount of irrigation water and frequency of irrigation are taken into account (Francis, 2000; ARB, 1997). Therefore, a more thorough investigation of irrigation effects on the climatic factor is advisable in future versions of the agricultural PM_{10} emissions inventory. Nevertheless, a C factor of 0.318 is considered conservatively acceptable for this agricultural PM_{10} emissions inventory.

For calculating PM_{10} emissions caused by wind erosion of cropland, the surface roughness factor, K, accounts for the resistance of wind blowing over ridges, furrows, or large clods in a field, and is influenced by crop type. Crop-specific values for K, LN, and V were obtained from U.S. EPA, 1977.

For calculating PM_{10} emissions caused by wind erosion of unpaved agricultural roads, the values of K= 1, LN = 0.32, and VN = 1 were used (ARB, 1997). The values for VN and K, respectively, reflect the lack of vegetative cover and the absence of ridges and furrows expected on unpaved roads. Although the wind angle on roads varies constantly, it is reasonable to assume that over the long term, wind direction is equally distributed for all roads. With this assumption, the value of LN becomes only a function of the product I x K (= 65.4 x 1 = 65.4) and is equal to 0.32 (U.S. EPA, 1977). Non-cropland agricultural aprons are areas of farmland that are no longer suitable, or not intended for, growing crops. These areas could include staging and turn-around areas. The same values of K= 1, LN = 0.32, and VN = 1 were therefore used for these other non-cropland areas.

After the emission factor was calculated, annual PM_{10} emissions were estimated for each of the subject areas based on the following equation:

$$Wind\ Erosion_{Crop} = EF\ H\ Acres\ H\ F$$

where:

$Wind\ Erosion_{Crop}$ = wind erosion emissions for each crop type (lbs PM_{10}/year);

EF = wind erosion emission factor (lbs PM_{10}/acre/year);

Acres = acres of cropland or non-crop land (acres);

F = fraction of Maricopa County farmland within PM_{10} non-attainment area.

The acres were determined as follows:

$ Cropland: From the Arizona Agricultural Statistics Report (ADOA, 2000).

- Non-cropland: From surveys of selected farmers as a fraction of cropland (Fish, 2000) areas. The survey results indicated that non-cropland areas as a fraction of cropland areas for cotton, wheat, and alfalfa crops were 0.02, 0.008, and 0.002, respectively. The surveys did not include information on any other crops. Consequently, the value of 0.008 for wheat was also used as a representative value for the remaining crops. The unpaved road areas around cotton, wheat, and alfalfa fields were reportedly 1500, 1200, and 1800 square foot per acre of farm, respectively. The value of 1200 square foot per acre for wheat was again used as a representative value for all remaining crops. (See Section 3.1.4, below, and Appendix E for more information on the survey.)
-

The same methodology used in the development of the Revised MAG 1999 Serious Area PM_{10} Plan (MAG, 2000) was used to calculate the PM_{10} emissions from wind erosion on the April 9 design day. The underlying assumption used in this methodology is that wind erosion is caused when wind speeds in excess of 15 mph are prevailing. In 1995, there were a total of 37 hours with a wind speed greater than 15 mph. Therefore, the average hourly emission rate was calculated by dividing the annual emissions by 37. Then, to calculate the emissions for the design day, the hourly emission rate was multiplied by 7, the number of hours with wind speed greater than 15 mph on April 9.

3.1.4 Travel on Unpaved Agricultural Roads

Re-entrained dust emissions from unpaved agricultural roads for the 1995 design-day were estimated using the emission factor equation located in Section 13.2.2 of AP-42 (U.S. EPA, 1995). Emissions were estimated based on activity data obtained for three different types of vehicles: pick-up trucks, heavy-duty trucks, and tractors. The re-entrained unpaved road dust emission factor equation is in the following form:

where:

EF	=	re-entrained unpaved road dust emission factor (lbs/VMT);
0.36	=	aerodynamic particle size multiplier for PM_{10};
5.9	=	constant;

s = silt content of road surface material (percent);
S = mean vehicle speed (mi/hr);
W = mean vehicle weight (ton); and
w = mean number of wheels (unitless).

A default soil silt content of 12% was used (U.S. EPA, 1995). This value is based on calculating the mean silt content for dirt roads, with silt contents varying between 1.6% and 67%. A limited survey of Maricopa County farmers was conducted with the assistance of the Maricopa County Farm Bureau in order to determine farm vehicle activity data (i.e., mean vehicle speeds, vehicle weights, and number of wheels), and unpaved road parameters (frequency and distance of travel and size of typical unpaved areas) (Fish, 2000). A summary of the survey results, along with the completed survey forms is located in Appendix E. The mean values for S, W, and w were calculated for both the maximum and average number of vehicle miles traveled (VMT) by each vehicle type. The parameter values estimated based on maximum VMT were used to calculate emissions for crops harvested in April, whereas the parameters estimated based on average VMT were used to calculate emissions for the remaining crops.

Daily re-entrained unpaved road dust emissions were then estimated by combining the calculated emission factor with VMT estimates for agricultural roads as follows:

where:

Unpaved = emissions (lbs PM_{10}/day);
EF = emission factor (lbs/VMT);
VMT = VMT estimate (VMT/day); and
F = fraction of Maricopa County farmland within PM_{10} non-attainment area.

3.2 Results

The 1995 design-day emissions estimates for agricultural sources are summarized in Table 3-3. These results show that cropland wind erosion was the most significant source of agricultural PM_{10} emissions on the April 1995 design day with 3,042,794 lbs (87.8% of the total). Non-cropland wind erosion was the next largest contributor to overall agricultural emissions with 325,895 lbs (9.4% of the total), comprising wind erosion of unpaved roads (203,886 lbs) and wind erosion of other areas (122,009 lbs). The remaining 2.8% of PM_{10} emissions are caused by tillage activities and dust re-entrainment on unpaved roads. These estimates are reasonable, especially considering the limited activity data that were available to calculate the emissions. More accurate estimates can be obtained if more accurate and detailed activity data are obtained through additional survey efforts.

Some significant issues and assumptions that influence the inventory results are as follows:

Table 3-3. Results of 1995 Design-Day Emissions Estimates of Agricultural Sources

Category	Activity	Design-Day Emissions (lbs/day)	Percentage of Total
Tillage and Harvest	Tillage	54,667	1.6%
	Harvest	0	0%
Non-Cropland	Wind Erosion	325,895	9.4%
	Unpaved Road Travel	41,561	1.2%
Cropland	Wind Erosion	3,042,794	87.8%
Total		**3,464,917**	**100%**

$

$ Tillage emissions are significantly influenced by the estimates of number of days of tilling. The estimate of tilling days by crop was based on detailed information provided by the University of Arizona Cooperative Extension (Clay, 2000a) and the Arizona Agricultural Statistics Report (ADOA,2000) and are believed to result in the most accurate estimate of tilling emissions available.

$ Very limited survey data were used to estimate the activity data for input into the unpaved road re-entrainment emissions and wind erosion from non-cropland emissions equations.

$ The silt content value of 35.2% determined in this analysis exceeds the U.S. EPA default value used in the ADEQ Microscale Study by approximately 95%.

$ Harvest emissions are zero for the design day, and are based on the calendar of typical activities published in the Arizona Agricultural Statistics Report (ADOA,2000). If harvesting of any crop (i.e., cotton, wheat, and barley are the only crops for which emission factors are available) actually occurred during April 1995, then these emissions have been underestimated. However, harvest emissions will be relatively small compared to emissions from other agricultural sources within the Maricopa County PM_{10} Non-Attainment Area.

$ The wind erosion estimates developed using U.S. EPA=s equation do not consider the effects of soil irrigation and resulting Acloddiness@ as a deterrent to wind erosion. Based on recent research by ARB (Francis, 2000), this approach can overestimate the climatic factor, and thus the emissions, by as much as 30%.

$ Daily wind erosion emissions were developed based on annual emissions, and adjusted for the number of hours with wind speeds exceeding 15 mph.

3.3 Comparison to Microscale Study Emissions Inventory

U.S. EPA disapproved ADEQ=s December 1997 Serious Area Plan because the plan failed to demonstrate attainment of the 24-hour PM_{10} NAAQS at the West Chandler and Gilbert monitoring sites. The analysis in the Serious Area Plan was based partially on the 1995 Phoenix PM_{10}

Microscale Field Study (ADEQ, 1997) which included the most significant fugitive dust sources:

- $ Road and housing construction;
- $ Paved and unpaved road dust re-entrainment;
- $ Industrial activities;
- $ Agriculture; and
- $ Wind erosion of cleared or disturbed areas.

Subsequently, ADEQ conducted an analysis of the emission sources and potential impacts from implementing agricultural BMPs in the vicinity of the West Chandler and Gilbert monitoring sites (ADEQ, 1999).

3.3.1 Objectives and Approach

The objective of this section is to compare the emissions inventory developed in this Agricultural BMP TSD to ADEQ=s Microscale Study emissions inventory for agricultural sources, and to determine how representative the Microscale Study inventory is compared to the larger non-attainment area inventory under similar conditions. The approach used for this comparison was to examine the following elements for each inventory:

- $ Temporal resolution;
- $ Spatial resolution;
- $ Agricultural emission source types;
- $ Emission estimating techniques (EETs); and
- $ Activity data.

3.3.2 Examination of Inventory Elements

Table 3-4 summarizes the inventory elements for the two inventories. The elements were identified for the Microscale inventory by reviewing the relevant TSDs (ADEQ, 1997; ADEQ, 1999), and through conversations with ADEQ staff (DeNee, 2000). The elements for the Agricultural BMP TSD inventory are documented in Section 3.1, above

Table 3-4. Summary of Inventory Elements

Inventory Element	Microscale Inventory	Agricultural BMP Inventory	Similarities and/or Differences
Temporal Resolution	Design Day: April 9, 1995	Design Day: April 9, 1995	Both inventories include 24-hour estimates for the April design day.
Spatial Resolution	Two 4-square mile domains surrounding the West Chandler and Gilbert monitoring sites.	The 2,880 square mile Maricopa County PM_{10} Non-Attainment Area.	The Microscale domain comprises about 0.28% of the non-attainment area. Furthermore, the emissions in the Microscale study were based on expected impacts at specific monitors, and not on area-wide emissions over the region.
Agricultural Sources	$ Wind erosion of agricultural fields; $ Wind erosion and travel on agricultural aprons; and $ Travel on unpaved agricultural roads.	$ Wind erosion of agricultural fields; $ Tilling; $ Wind erosion and travel on agricultural aprons; and $ Wind erosion and travel on unpaved agricultural roads.	Harvest emissions were considered non-existent for both inventories. The Agricultural BMP inventory included tilling and unpaved road wind erosion, while the Microscale inventory did not. Crops observed in Microscale study were cotton (West Chandler) and alfalfa (Gilbert).
Emissions Estimating Techniques	Wind Erosion		

Inventory Element	Microscale Inventory	Agricultural BMP Inventory	Similarities and/or Differences
	Emission factor derived from Nickling and Gillies, 1986. Variables include wind speed, fetch length.	Emission factor from USDA WEQ. Variables include soil erodibility, climatic factor, surface roughness.	ADEQ=s EET was based on wind tunnel studies conducted using Arizona soils, and is appropriate when local site conditions (e.g., field fetch length) are known. USDA WEQ is suitable for estimating emissions on a regional basis.
	Tillage		
	Not applicable.	U.S. EPA, 1995, Section 9.1	No tilling was observed at either the West Chandler or the Gilbert locations on April 9, 1995.
Emissions Estimating Techniques (Cont.)	Unpaved Area Travel (Aprons and Roads)		
	U.S. EPA, 1995, Section 13.2.2	U.S. EPA, 1995, Section 13.2.2	The same EET was used for both inventories.
Activity Data	Wind Erosion		
	$ Wind speed based on measurements for April 9, 1995; $ Fetch length based on measurements for fields impacting West Chandler and Gilbert monitors; $ Field sizes from	$ Wind speed based on measurements for April 9, 1995; $ Wind erosion was assumed to occur during hours when speed exceeded 15 mph. $ AC@ factor from MAG,	Differences in EETs create significant differences in the types of activity data needed to estimate emissions for the two inventories. Microscale data focus on site-specific measurements, while Agricultural BMP data were obtained from county-level statistics and scaled down to the non-attainment area.

Inventory Element	Microscale Inventory	Agricultural BMP Inventory	Similarities and/or Differences
	measurements; and $ Unpaved area sizes from aerial photos.	2000; $ Soil silt and erodibility factors derived from SSURGO database; $ Field sizes and crop types from ADOA, 2000; and $ Unpaved area sizes from surveys.	
	Tillage		
	Not applicable.	$ Silt content derived from SSURGO database; $ Number of tilled acres from ADOA, 2000; and $ Number of acre-passes by crop from Clay, 2000.	
Activity Data (Cont.)	Unpaved Area Travel (Aprons and Roads)		
	$ Traffic volume from county statistics for 1995; $ Default silt content of 12%; $ Vehicle characteristics	$ Traffic volume from surveys; $ Default silt content of 12%; $ Vehicle characteristics (speed, weight, number	Data for Microscale inventory is consistent with data used in other ADEQ inventories. The survey conducted under the Agricultural BMP study was very limited.

Inventory Element	Microscale Inventory	Agricultural BMP Inventory	Similarities and/or Differences
	(speed, weight, number of wheels) from county statistics based on averages for unpaved road travel.	of wheels) from surveys.	

Notes:

BMP = Best Management Practice
EET = Emission estimating technique
SSURGO = Soil Survey Geographic (Database)
USDA = United States Department of Agriculture
WEQ = Wind erosion equation

The significant differences and similarities between the inventories are as follows:

$ Tillage emissionsB these are estimated in the Agricultural BMP inventory but are not included in the Microscale inventory since no tillage occurred on the design day within the West Chandler and Gilbert domains;

$ Wind erosion EET- these are significantly different for each inventory; the Microscale inventory has a local focus while the Agricultural BMP inventory has a regional focus;

$ Wind erosion of unpaved roadsB these are estimated for the Agricultural BMP inventory but are not included in the Microscale inventory;

$ Unpaved road and area travelB while the EET is the same for both inventories, the sources of activity data used in the EET are different; however, the actual values used are comparable (e.g., average number of wheels for the Microscale inventory are 4.0, and for the Agricultural BMP inventory are 4.46; silt value of 12% is the same for both inventories);

3.3.3 Conclusions

Although the Agricultural BMP inventory included two agricultural sources that were not estimated in the Microscale inventory (i.e., tillage and wind erosion of unpaved surfaces), the relative amount of emissions contributed by these sources to the overall Agricultural BMP design-day emissions estimate is insignificant (i.e., 54,667 lbs and 203,886 lbs, respectively, or 7.5% of the total Agricultural BMP design-day emissions).

The most significant difference between these two inventories is with regard to the wind erosion EETs. Even though the EETs are different, they are appropriate for use in their particular cases. It would not be feasible to use the Microscale wind erosion EET on a regional basis since it would require extensive data collection in order to determine fetch length on a field-by-field basis. Furthermore, the emission rate calculated for the Microscale study takes into consideration the wind direction and portions of the fields adjacent to the West Chandler and Gilbert monitoring sites that would actually impact these monitors, thus this approach would not be appropriate for use on a regional basis.

Because of the inherent differences in the wind erosion EETs and the intended uses for the two inventories, (i.e., microscale assessment versus non-attainment area assessment), it is not appropriate to compare the results of the inventories. Although it cannot be concluded that the Microscale results are indicative of the larger non-attainment area under the same conditions, it can be stated that the two methods used for estimating wind erosion are appropriate for their specific spatial resolutions and intended purposes. Also, since both inventories demonstrate the relative significance of wind erosion of agricultural lands compared to other agricultural related sources, they both support a focus on control of these emissions in order to attain the 24-hour PM_{10} NAAQS in the Maricopa County PM_{10} Non-Attainment Area.

4.0 AGRICULTURAL EMISSIONS FOR 2006

Understanding and estimating the impact on daily PM_{10} emissions is the overall objective of this TSD. Section 2.0 describes the information obtained, and analysis conducted to estimate the individual control levels achievable though implementation of the BMPs. Table 2-3 lists the BMPs most likely to be implemented. The remainder of this section explains the method used to estimate the potential emission reductions, presents the results of the emissions projections to the year 2006, and summarizes the overall emission reductions expected through compliance with the Agricultural PM_{10} General Permit.

4.1 Methodology

The methodology for projecting the 1995 design-day emissions to the year 2006 involved three steps:

$ First, the net control efficiency range (i.e., minimum, maximum, mid-point) expected from implementation of each BMP by crop was determined (see Table 2-3) ;

$ Second, the percentage of agricultural land going out of production by 2006 was determined to be approximately 37% (i.e., the corresponding land use factor is 0.6265) based on information obtained from MAG (MAG, 1999); and

$ Third, the mid-point net control efficiency for each BMP by crop, and the percentage of land going out of production by 2006 were applied to the design-day estimates to estimate year 2006 emissions.

4.2 Results

The 2006 projected emissions estimates for agricultural sources are summarized in Table 4-1. As the table shows, cropland wind erosion is the most significant source of PM_{10} emissions on a daily basis for 2006 (81.9% of the total). Wind erosion of non-cropland is the next most significant source (14.8% of the total).

Table 4-2 summarizes the emission reductions expected through compliance with the General Permit. The total reduction was calculated by adding the reduction expected from agricultural lands going out of production (i.e., approximately 37% of the daily emissions) to the

Table 4-1. Results of 2006 Design-Day Projected Emissions Estimates of Agricultural Sources

Category	Activity	Projected Emissions (lbs/day)	Percentage of Total
Tillage and Harvest	Tillage	23,467	1.7%
	Harvest	0	0.0%
Non-Cropland	Wind Erosion	204,186	14.8%
	Travel on Unpaved Roads	21,528	1.6%
Cropland	Wind Erosion	1,126,101	81.9%
Total		**1,375,282**	**100%**

Table 4-2. Summary of Design-Day Emission Reductions Achievable Through Compliance with the Agricultural PM_{10} General Permit

Category	Activity	Total Design-Day Emissions[a] (lbs/day)	Land Use Reduction[b] (lbs/day)	BMP Implementation Scenario				Total Reduction[d] (lbs/day)		
				BMP	BMP Reduction[c] (lbs/day)			Minimum	Maximum	Mid-Point
					Minimum	Maximum	Mid-Point			
Tillage and Harvest	Tillage	54,667	20,416	Combining Tractor Operations	2,396	3,423	2,910	30,686	31,713	31,200
				Limited Activity During High-Wind Events	3,423	3,423	3,423			
				Multi-Year Crops	4,450	4,450	4,450			
	Harvest	0	0	Combining Tractor Operations	0	0	0[e]	0	0	0
				Reduced Harvest Activity	0	0	0[e]			
Non-Cropland	Unpaved Road Travel	41,561	15,521	Access Restriction	0	311	156	16,248	23,820	20,034
				Reduced Vehicle Speed	726	7,987	4,357			

Category	Activity	Total Design-Day Emissions[a] (lbs/day)	Land Use Reduction[b] (lbs/day)	BMP Implementation Scenario				Total Reduction[d] (lbs/day)		
	Wind Erosion	325,895	121,709	NA[f]				121,709	121,709	121,709
Cropland	Wind Erosion	3,042,794	1,136,362	Multi-Year Crops	359,556	359,556	359,556	1,829,321	2,004,065	1,916,693
				Residue Management	109,679	256,457	183,068			
				Timing of Tilling Operations	139,828	167,793	153,810			
				Planting Based on Soil Moisture	83,897	83,897	83,897			
Total			**1,294,008**				**795,627**	**1,997,964**	**2,181,307**	**2,089,636**

Notes:

[a] Emissions are total design-day emissions for <u>all</u> crops.

[b] Land Use Reduction = (design-day emissions) x (1 - land use factor of 0.62654).

[c] BMP Reduction = (design-day emissions for BMP-applicable crops) x (land use factor of 0.62654) x (net control efficiency).

[d] Total Reduction = (Land Use Reduction) + (BMP Reduction).

[e] Emission reductions are zero because design-day emissions are zero for harvest.

[f] No BMPs applicable to non-cropland wind erosion were included in the implementation scenario.

range of BMP reductions. The range of BMP reductions were estimated by applying the BMP net control efficiencies (i.e., minimum, maximum, and mid-point) to the daily emissions for the crops subject to that BMP (minus the 37% reduction attributable to land going out of production). An overall emission reduction of 60.3% from the 1995 design-day emission is predicted based upon the mid-point BMP reduction. (It should be noted that if the 37% land use reduction is not considered, the overall emission reduction is 36.6% due solely to BMP implementation.)

Some significant issues and assumptions that influence the 2006 projected emissions estimates and reductions are as follows:

$ The implementation scenario includes a set of BMPs that were selected based on their likelihood for implementation. The BMPs that are eventually implemented may or may not comprise those quantified in the implementation scenario. Actual reductions may be more or less than those quantified on Table 4-2.

$ The net control efficiency for each BMP uses, in many cases, control efficiency data gleaned from the literature search. Most of these research documents reported results from studies conducted in other areas of the country. The control efficiencies may not be indicative of control levels attainable in Maricopa County.

5.0 REFERENCES

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Literature Search Record

Title: AAgricultural Air Quality Fine Particle Project B Task 1, 2, and 3 Final Reports@

Type (brochure, journal article, report, etc.): Texas A&M and Texas Agricultural Experiment Station Report B 1999

Summary of content:
Task 1 Final Report addresses livestock and feedlot PM emission factors and emissions inventory estimates. Task 2 Final Report covers tilling, harvesting, and loading emission factors and emissions inventory estimates. Task 3 Final Report focuses on prescribed burning emission factors and emissions inventory estimates. Only the Task 2 Final Report is applicable; the Task 1 and Task 3 Final Reports will not be reviewed in detail.

Seasonal emissions inventories for six major crops (corn, cotton, sorghum, soybeans, wheat, and hay) were prepared on the county-, Agricultural Extension Service district-, and state-level.

Three emission factors were used: low emitting field operation (0.1 lbs/acre), medium emitting field operation (0.25 lbs/acre), and high emitting field operation (0.5 lbs/acre). Only the high emitting field operation emission factor is based upon literature B 1995 UC Davis report. Other emission factors appear to be based upon engineering judgement.

Control efficiency information: Control strategies are not included.

Follow-up action:
A phone call to principal investigator regarding the use of engineering judgment emission factors will be made.

Name of reviewer: Marty Wolf

Date: September 11, 2000

Literature Search Record

Title: AControlling Particulate Matter Under the Clean Air Act: A Menu of Options@

Type (brochure, journal article, report, etc.): STAPPA/ALAPCO Report B 1996

Summary of content:
Document focuses on PM control strategies, their effectiveness, and associated costs. All significant PM sources are included in the document; fugitive dust source information is limited to less than 10 pages.

Control efficiency information:
General control strategies are described, but no specific control efficiencies are provided.

Follow-up action: No follow-up action required

Name of reviewer: Marty Wolf

Date: September 11, 2000

Literature Search Record

Title: AInterim Report of the Northwest Columbia Plateau Wind Erosion Air Quality Project@

Type (brochure, journal article, report, etc.): Interim WSU Report B 1996

Summary of content:
Document includes a large number of research articles with several articles focusing specifically on control measures for irrigated lands. Cropland controls are primarily concerned with preserving soil stability, roughening the soil surface, and utilizing vegetative cover.

Control efficiency information:
In Chapter 1, control strategies are not described for specific BMPs. However, an empirical relationship showing the relative soil loss ratio for different values of surface random roughness and flat residue cover is provided. These could be used to derive control efficiencies for the Residue Management and Surface Roughening BMPs.

In Chapter 3, several control strategies are discussed (see Figures 3.3 and 3.7):

- Ridges (approximately 20-80%);
- Crustant/Synthetic Particulate Suppressant (<20-40% for fields);
- Cover Crop (20-65%);
- Residue Management w/ Straw (50-55%); and
- Frozen Ripping/Surface Roughening (75%).

Follow-up action: An additional call might be needed to clarify some of the control measures and control efficiencies described in the article.

Name of reviewer: Marty Wolf

Date: September 11, 2000

Literature Search Record

Title: AFarming with the Wind B Best Management Practices for Controlling Wind Erosion and Air Quality on Columbia Plateau Croplands@

Type (brochure, journal article, report, etc.): WSU Report B 1998

Summary of content:
Handbook includes several sections focusing specifically on control measures for irrigated lands. Some material is taken from the 1996 interim WSU report. Cropland controls are primarily concerned with preserving soil stability, roughening the soil surface, and utilizing vegetative cover.

Control efficiency information:
Several control strategies with control efficiencies are provided in the document. Some control efficiencies include:

$ Cover crops (a canopy cover of 65-90% can be obtained from triticale and winter/spring wheat B unclear of actual control efficiency);

$ Residue Management and Surface Roughening (an empirical relationship showing the relative soil loss ratio for different values of surface random roughness and flat residue cover is provided which could be used to derive control efficiencies for the Residue Management and Surface Roughening BMPs B it is similar to an equation in the 1996 interim WSU report, but one of the factors is different).

$ Other control efficiencies from the 1996 interim WSU report are cited in this document also.

Follow-up action:
An additional call might be needed to clarify some of the control measures and control efficiencies described in the article.

Name of reviewer: Marty Wolf

Date: September 11, 2000

Literature Search Record

Title: ABest Available Control Measures PM_{10} SIP for the South Coast Air Basin B Appendix I-D@

Type (brochure, journal article, report, etc.): SCAQMD B SIP supporting documentation.

Summary of content:
Document identifies PM_{10} BACM for the South Coast Air Basin PM_{10} SIP. Specific control strategies for agricultural activities are not discussed or quantified. Instead, the proposed method of control is that soil conservation plans will be developed.

Control efficiency information:
None, SCAQMD did not estimate emissions because of uncertainty.

Follow-up action: None.

Name of reviewer: Marty Wolf

Date: September 11, 2000

Literature Search Record

Title: AMethodologies for PM_{10} Categories@

Type (brochure, journal article, report, etc.): Summary of PM_{10} methodologies. Unknown source. Appears to have been done for California.

Summary of content:
Identifies methodologies for various PM_{10} source categories. Most identified methodologies are standard. Some notable assumptions include 50 vehicle miles per year per 40 acre lot (for grapes) and 175 vehicle miles per year per 40 acre lot (for non-grape crops). Also an assumption that windblown dust from pastures and fruit and nut orchards is insignificant. Basis for these assumptions is unknown.

Control efficiency information: None.

Follow-up action: None. Because of limited documentation, these may not be usable.

Name of reviewer: Marty Wolf

Date: September 12, 2000

Literature Search Record

Title: ACotton Tillage/Quantification of Particulate Emissions B Final Report: 1991-94 Trials@

Type (brochure, journal article, report, etc.): Final report prepared for ADEQ under contract by University of Arizona professor.

Summary of content:
Significant information regarding cotton tillage is provided. Some details provided below. The use of silt content values in the tillage equation is discussed with a comparison between free state silt content values and measured levels of conglomeration. Emission factors for conventional tillage and reduced tillage systems are also provided. Comparisons made between predicted and measured tillage emissions B in general AP-42 overestimates emissions for Arizona.

Control efficiency information:
Information from tillage testing could be used to derive control efficiencies for Combining Tractor Operations and Reduced Tillage System BMPs. Control efficiencies of 35-50% may be possible.

Follow-up action:
A follow-up call with Professor Coates might be useful to see if any additional research has been conducted. These may not be usable.

Name of reviewer: Marty Wolf

Date: September 12, 2000

Literature Search Record

Title: 3 documents by CARB staff (copies are attached to this record):

35. AImproving PM_{10} Fugitive Dust Emission Inventories,@ Patrick Gaffney, Dale Shimp. No date.

36. ADevelopment of an Improved Method for Estimating Fugitive PM_{10} Emissions from Windblown Dust from Agricultural Lands,@ Stephen R. Francis, Skip G. Campbell, and Dale R. Shimp.

37. ASpatial Distrbution of PM_{10} Emissions from Agricultural Tilling in the San Joaquin Valley,@ Shimp, Campbell, Francis. No date.

Type: All 3 appear to be technical papers prepared for Air and Waste Management Association (A&WMA) conference(s)

Summary of content:
Paper 1: Documents recent CARB activities to improve methods used, and results of emissions inventory of these area sources:

- Paved and Unpaved Road Dust
- Construction Operation Dust
- Agricultural Land Preparation and Harvest Dust
- Agricultural Windblown Dust

In general, a Abottom-up@ approach was used (versus previous Atop-down@ approach) and emission factors and their inputs were improved upon by collecting California-specific data.

Paper 2: Provides details on CARB=s work to modify U.S. EPA=s wind erosion equation (WEQ) for agricultural windblown dust. Because EPA=s equation (Es = AIKCL=V=) was based on tests of a large, flat, bare field in Kansas, many of the geologic and meteorologic conditions, and agricultural practices from that area are not indicative of California. In particular the following adjustments were made:

- Development of a monthly AC@ factor that would apply if the climate for a given month were instead the year-round climate.
- Crop calendars were developed based on significant amounts of data collected from farmers, and used to account for factors such as crop canopy cover, postharvest soil cover, irrigation, and replanting.
- Adding a short-term irrigation factor for wetness

Overall, there was as dramatic drop in the annual emissions estimate of approximately 80% statewide compared to emissions estimated using a previous ARB version of EPA=s WEQ.

<u>Paper 3:</u> PM_{10} emissions were estimating using AP-42 methods for agricultural tilling, and then spatially distributed within the counties under the study. The map provides planners with an estimate of the relative range of agricultural tilling emissions.

Control efficiency information: None.

Follow-up action: None.

Name of reviewer: Paula Fields

Date: September 15, 2000

Literature Search Record

Title: AEffectiveness of polyacrylamide (PAM) for wind erosion control@ by D.V. Armbrust

Type: Article in AJournal of Soil and Water Conservation@ Third Quarter 1999, Pages 557-559

Summary of content:

Tests showed that PAM is not more effective than natural rainfall for wind erosion control under general agricultural conditions.

Control efficiency information: See above.

Follow-up action: None.

Name of reviewer: Paula Fields

Date: September 15, 2000

Literature Search Record

Title: AWind velocity patterns as modified by plastic pipe windbarriers,@ by J.D. Bilbro and J.E. Stout

Type: Article in AJournal of Soil and Water Conservation@ Third Quarter 1999

Summary of content:
Study of the efficiency of plastic pipe windbarriers to reduced wind velocity, and decrease soil erosion.

Control efficiency information:

12% optical density gives average of only 4.3% reduce in wind velocity
75% optical density gives average of 32.5% reduction in wind velocity

Follow-up action: None.

Name of reviewer: Paula Fields

Date: September 15, 2000

Literature Search Record

Title: ACalifornia Agriculture@ July-August 1998, Vol. 52, Number 4

Type: Journal

Summary of content:
Contains several articles written by UC Riverside, CARB, and other researchers on the topic of control emissions from agricultural soils. In particular, these articles are relevant to ADEQ study:
AThough difficult to achieve, revegetation is best way to stabilize soil@ (Pgs. 8-13)
AWind barriers offer short-term solution to fugitive dust@ (Pgs. 14-18)

Control efficiency information:
Revegetation to control surface disturbance in arid regionsCwhether from abandoned agriculture, overgrazing, or recreational activities. Direct seeding effectiveness for control of fugitive dust at 3.3 feet above the ground during wind gusts above 34 mph: 91.0 to 99.5%.

Control of fugitive dust by various types of wind barriersCranges from 15-86% (see attached for table).

Follow-up action:

Name of reviewer: Paula Fields

Date: September 13, 2000

Literature Search Record

Title: ACalifornia Agriculture@ July-August 1998, Vol. 52, Number 4

Type: Journal

Summary of content:
Contains several articles written by UCRiverside, CARB, and other researchers on the topic of control emissions from agricultural soils. In particular, these articles are relevant to ADEQ study:
AThough difficult to achieve, revegetation is best way to stabilize soil@ (Pgs. 8-13)
AWind barriers offer short-term solution to fugitive dust@ (Pgs. 14-18)

Control efficiency information:
Revegetation to control surface disturbance in arid regionsCwhether from abandoned agriculture, overgrazing, or recreational activities. Direct seeding effectiveness for control of fugitive dust at 3.3 feet above the ground during wind gusts above 34 mph: 91.0 to 99.5%.

Control of fugitive dust by various types of wind barriersCranges from 15-86% (see attached for table).

Follow-up action:

Name of reviewer: Paula Fields

Date: September 13, 2000

Literature Search Record

Title: AParticulates Generated by Five Cotton Tillage Systems@ by W. Coates

Type: Transactions of the American Society of Agricultural Engineers (ASAE), Vol. 39(5):1593-1598

Summary of content:
Reduced tillage systems such as Uprooter-Shredder-Mulcher (USM), a stalk pulling system and a modified conventional system were shown to produce significantly fewer particulate emissions than a conventional tillage system. The Sundance uprooter was associated with the greatest emissions, while the USM implement and disking produced the fewest emissions. Both the number and type of operation influenced tillage system emissions, with the measured emissions being half of those predicted by EPA=s AP-42 tillage emission factor equation. ***This indicates that the equation cannot be relied upon to predict emissions from cotton tillage operations.***

Control efficiency information:
None.

Follow-up action:
None.

Name of reviewer: Paula Fields

Date: September 15, 2000

Literature Search Record

Title: The Role of Agricultural Practices in Fugitive Dust Emissions, Draft Final Report, April 17, 1981. Prepared by Midwest Research Group for CARB.

Type: Technical Report

Summary of content:
Thirteen tests were performed in the spring of 1980 to quantify emission factors from discing and land planning and vehicular traveling on unpaved farm roads. Six tests were performed in the fall of 1980 to quantify emission factors from sugar beet harvesting. Five tests were performed in the spring of 1980 to quantify the visibility impact of fugitive dust from land planing, discing, and vehicles traveling on unpaved roads. Fields crops yielded the most significant emissions while soil preparation was the most significant category of operations. (Note: This research is either the basis of emission factors recommended by U.S. EPA in AP-42 or ARB, or not relevant to the ADEQ project [i.e., sugar beet harvesting].)

Two categories of controls were suggested: (1) those that included control equipment to be added to the farm implement (e.g., fogger with electrostatic precipitation), and (2) those that included operational modifications. Control efficiencies and potential emission reductions were estimated for these control techniques.

Control efficiency information:
C-E for foggers and foggers augmented with ESP is 65-75% reduction in dust. A table of control efficiencies for the various controls examined is attached to this record. The control techniques are defined below:

Activity Affected	Control	Definition
Tilling/Planing/ Discing/Land Prep	Low energy system	Min. tillage technique that confines all vehicle traffic to traffic corridors; eliminates land prep. operations.
	Herbicides	Controls weeds, helps to eliminate need for cultivation
	Sprinkler irrigation	Eliminates need for extensive land planing and surface irrigation.
	Laser-directed land plane	Reduces the amt of land planing
	Develop high-quality alfalfa	Reduces frequency of replanting
	Double crop corn w/wheat	Reduces a plowing/discing operation and a bed forming operation; adds a less dusty wheat stubble removal operation.
Planting	Punch planter	Punches a hole vs. harrowing
	Plug planter	Places plants more exactly, eliminating need for thinning
	List tomato acreage in the fall	Might eliminate need to harrow and roll in the spring.
	Aerial seeding	Produces less dust than ground planting
All operations	Fogger	Electrostatically charged fine-mist water spray

Follow-up action: None.

Name of reviewer: Paula Fields
Date: September 14, 2000

Literature Search Record

Title: AStrategy Development for Dust Control and Prevention on I-10@ by Midwest Research Institute (MRI) for ADOT. Final Report, June, 1997.

Type: Technical Report

Summary of content:
Discusses causes and mitigation of dust events that have historically caused accidents on Arizona Interstate 10 (I-10). Causes are wind erosion of desert lands, including deserted agricultural lands. Controls are generally discussed and conform to types and effectiveness published in other EPA and MRI studies.

Internet search of Kansas State University website **http://www.weru.ksu.edu** is encouraged for identifying current control information.

Soil samples were taken and reported in terms of Athreshold friction velocity@ needed to suspend particles (not useful for ADEQ study since a difference method will be used for estimating emissions than that which uses threshold friction velocity.)

USDA staff at Big Springs, Texas, characterized the effectiveness of crop residues to reduce wind erosion. Figure 5 shows the relationship of soil cover to soil loss ration (SLR) as ascertained from the wind tunnel studies by Bilbro and Fryrear.

Control efficiency information:
No specifics, just references to previous EPA and MRI studies.

Follow-up action:
Review Kansas State University website.

Name of reviewer: Paula Fields

Date: September 15, 2000

Literature Search Record

Title: AGuide to Agricultural PM_{10} Dust Control Practices,@ South Coast Air Quality Management District

Type: Brochure

Summary of content:
Focus on Aconservation practices@ that control dust in support of SCAQMD Rule 403 (no visible dust on the property line) and Rule 1186 (requires dust control on all fugitive sources). Practices are categorized by:

_ Activity modification
_ Inactive practices (e.g., cover crop, field windbreaks, ridge roughness)
_ Farm yard area
_ Track-out
_ Unpaved roads
_ Storage pile

A Aconservation practice self-monitoring form@ is provided.

Control efficiency information:
None.

Follow-up action:
None.

Name of reviewer: Paula Fields

Date: September 11, 2000

Literature Search Record

Title: AFinal Staff Report for: Proposed Amended Rule 403CFugitive Dust,@ South Coast Air Quality Management District, December 11, 1998 and ARevised Final Staff Report for: Proposed Amended Rule 403CFugitive Dust, and Proposed Rule 1186CPM_{10} Emissions from Paved and Unpaved Roads, and Livestock Operations,@ February 14. 1997.

Type: Techn. Paper

Summary of content:

1998 paper: Gives background and activities leading up to proposed rule. Sections include AAffected Operations,@ and AEmissions Reductions@ among others. States: AThe proposed amendments to Rule 403 would delay an estimated 8.9 tons/day of PM_{10} emission reductions for six months from January 1, 1999 to July 1, 1999. (February 1997 Rule 403 Staff Report projected a 42.9 ton/day reduction of PM_{10} by the year 2006 for all the Rule amendments.)@

1997 paper: Appendix F titled AEmission Reductions Estimates@ (see attached) provides calculations of uncontrolled and controlled emissions.

Control efficiency information:

Appendix F gives control efficiencies for each BMP:
BCM 1a: Minimal Track-out
BCM 2: Wider Use of Plans
BCM 4: Agricultural activities (soil erosion control, ag tilling controls)
BCM 6: RACM/BACM upgrades
BCM 3: Unpaved roads
(See attached copies for details)

Follow-up action:

None.

Name of reviewer: Paula Fields

Date: September 11, 2000

Literature Search Record

Title: ARule 403 Implementation@ South Coast Air Quality Management District, January 1999

Type: Booklet

Summary of content:
Gives a copy of the fugitive dust rule (#403), how to test for soil testing (ASTM methods D2216 and D1557), how to calculated areas and silt content of storage piles, and complete descriptions of each RACM and BACM that apply to the various fugitive dust sources.

Control efficiency information:
None.

Follow-up action:
None.

Name of reviewer: Paula Fields

Date: September 13, 2000

Literature Search Record

Title: AParticulate Control Measure Feasibility Study,@ by Sierra Research for Maricopa Association of Governments. January 24, 1997. Volume I (Appendices: Volume II)

Type: Technical Report (Final)

Summary of content:
To support their SIP efforts, a study was sponsored to MAG to evaluate sources of PM_{10} emissions and feasibility controls. The sources examined included:

- Paved and ***Unpaved Roads***
- Industrial Paved Roads
- Construction
- ***Agricultural Tilling***
- Residential Wood Combustion
- Vehicle Exhaust
- ***Wind Erosion***
- PM_{10} precursors (NO_x and NH_3)

(Bold indicates sources relevant to ADEQ BMP project)

Control and cost effectiveness for various controls was calculated. Control efficiency multiplied by Asource extent@ (i.e., percentage of area or other parameter to which the control is applied) is used to determine overall reductions achievable by each control.

Control efficiency information:
The following control efficiencies are provided from various sources (only information for ADEQ study is listed):

- Open lots: Vegetative and chemical stabilization = ??
- Open lots: Windbreaks = 25%
- Tilling: Prohibit tilling or soil mulching during high wind events = ??
- Wind erosion of fallow fields: cover trop, grass revegetation (if irrigated), maintain crop residues (if not irrigated), mowing for weed control = 50% (all)

Detailed example calculations of emissions, emission reductions, and cost effectiveness are contained Vol. II of this document.

Follow-up action:
None.

Name of reviewer: Paula Fields

Date: September 16, 2000

Literature Search Record

Title: ΑFarming with the Wind: Best Management Practices for Controlling Wind Erosion and Air Quality on Columbia Plateau Croplands,@ by Washington State University, Washington State Dept. of Ecology, etc.,

Type: Report

Summary of content:
Covers the various BMPs for dry and irrigated crop land. Agricultural wind erosion control from wind breaks is explained in terms of soil loss ratio (SLR). All work done for crops, soils, and practices found in eastern Washington, and may not be applicable to Arizona.

Contains an informative discussion regarding background and effect of the Conservation Reserve Program (CRP).

Control efficiency information:
None.

Follow-up action:
None.

Name of reviewer: Paula Fields

Date: September 15, 2000

Telephone Call Record

Person Contacted: Dr. Allan Kosecki, Affiliation: Maricopa Association of Governments
Telephone: 602-254-6300
Date of Contact: 9/21/00
Subject: Projection Factors Used to Estimate Conversion of Agricultural Land to Non-Agricultural Land from 1995 to 2006

Summary:

What are the appropriate projection factors needed to estimate the amount of conversion of agricultural land to non-agricultural land between 1995 and 2006?

The appropriate projection factors are based upon historical data trends from 1979 to 1994. A slight upward adjustment has also been made to account for the effects of the 1995 Farm Bill which eliminated the agricultural set aside program. A description of the technical analysis is provided in a July 1, 1999 memo written by Dr. Kosecki for the Maricopa Association of Governments' internal file.

Dr. Kosecki indicated that the appropriate projection factors can be calculated from data provided in Table 1 of the memo mentioned above. The 1995 agricultural acreage is 293,897 acres and the 2006 agricultural acreage is 184,139 acres. Dividing the 2006 acreage by the 1995 acreage gives a projection factor of 0.62654.

Follow-up Action: None

Person Contacting: Marty Wolf, ERG

Telephone Call Record

Person Contacted: Dr. Glenn Wright, UA Coop Extension, Yuma
Telephone: 520-726-0458
Date of Contact: 9/11/00
Subject: Tilling and land-work activities for citrus crops in Maricopa County

Summary:

Are there crop budget reports for citrus? No.

Explain the annual citrus cycle:
Lifetime of a citrus grove (e.g., 40-acre block is a section) is avg. 25 years.
Planting occurs early-March to mid-June. Limited fall planting (end-Sept. to mid-Oct.) Prior to planting these activities occur:

- Push out old orchard
- Disk (day 1)
- Chisel (day 2)
- Level (rest 2 days, level on 5^{th} day)
- Plant

How to determine the amount of citrus planted in 1995?
Per Sunkist lemon report: Total non-baring (i.e., <6 yrs. Old) acres: 246
Total baring acres: 1,073
He only had lemons and suggested that I call Claire Gervis at Az. Ag. Statistics office 602-280-8850 for better data on all citrus crops.

Dr. Wright's best estimate for non-baring acres per baring acre is 15%-20% per year. Thus, for every 1,000 acres harvested, about 150-200 acres would have been planted that same year.

Got Dr. Wright's number from Michael Kilby at UA Extension Office in Tucson 520-621-1400. He knew about tree and fruit crops, but not citrus.

Follow-up Action: Call Claire Garvis at AAS office.

Person Contacting: Paula Fields, ERG

Telephone Call Record

Person Contacted: Dr. Philip DeNee, ADEQ
Telephone: (602) 207-2355
Date of Contact: 10/18/00
Subject: Micro-Scale Study Emissions Inventory: Sources, Methods, and Activity Data

Summary

For which agricultural sources did you estimate emissions at the West Chandler and Gilbert Sites? Agricultural fields (wind erosion), agricultural aprons (wind erosion and re-entrainment); and, unpaved agricultural roads (re-entrainment). No tillage or harvesting was observed on the April 9, 1995 design day.

Which crops were planted in the fields? Cotton at West Chandler; alfalfa at Gilbert..

Explain the emission estimation methods that you used.

$ Wind erosionB Used a modified WEQ adapted from wind tunnel studies in Arizona. This is suited for site-specific calculations because it requires Afetch length@ as an input parameter. The EPA WEQ is a gross estimation compared to the equation we used.

$ Re-entrainmentB Used EPA=s equation from AP-42.

Describe the sources of activity data that you used.

$ Wind erosion- Wind speeds from measurements on April 9, 1995; fetch length from measurements in the field for the West Chander and Gilbert sites. (Note: these are documented in the ADEQ, 1999.)

$ Re-entrainment- Default silt of 12%; vehicle speed, weight, and wheels from county-level profiles used in previous inventories (i.e., 4 wheels average; 20 mph average); average daily traffic (ADT) counts from county data for unpaved roads.

Follow-up Action: None.

Person Contacting: Paula Fields, ERG

Telephone Call Record

Person Contacted: Eric Wolfbrandt, Arizona Department of Agriculture
Telephone: (602) 280-8822
Date of Contact: 9/21/00
Subject: Use of SSURGO Tables to Calculate Silt Content of Agricultural Land

Summary

I asked Eric about the many-to-one problem with merging the Comp table entries with the layer and mapunit tables.

Eric suggested that I separate the component sequence numbers and merge one at a time.

I agreed that it was a good idea and proceeded to use this approach.

Person Contacting: Venus Sadeghi, URS Corp.

Telephone Call Record

Person Contacted: Patrick Clay, Maricopa County Cooperative Extension
Telephone: (602) 470-8086 ext. 313
Date of Contact: 9/27/00
Subject: Number of Days of Agricultural Tilling

Summary

I asked Pat to clarify the following points regarding the tilling periods and number of tilling hours (spreadsheets) that he sent us:

- Why were there no tilling activity hours specified for wheat and barley, whereas these crops had associated acre-passes?
- If the number of tilling activity hours by farm were to be multiplied by the number of farms, the resulting total hours would be unrealistically large. Could the hours be used without multiplying by the number of farms and then divided by 8 or 10 to obtain the number of days?

Regarding the first point, Pat responded that wheat and barley indeed did have associated hours and gave me a formula to calculate them (number of acre-passes/acres/20).

Regarding the second matter, Pat clarified that if the number of farms were not taken into account, the underlying assumption would be that all the tilling activities for all the farms occurred on the same days. This assumption would lead to an underestimation of the number of days. On the other hand, the number of hours listed were actually per farm equipment (e.g., tractor). Therefore, the true number of hours of tilling in a day could be much more than 8 to 10 hours, based on how many equipment were working on the field.

Since there was no practical way to determine the number of farm equipment on a given day, I suggested we do not use the number of hours, but rather use the period of tilling activity (e.g., March through April) which Pat had also supplied.

Pat responded that a normal distribution of activity over the period would have to be assumed, with activities ramping up towards the middle of the period and ramping down towards the end. For a 90-day period, for example, he suggested 10% activity level over the first and last 15 days, 20% activity level over the second and one-to-last 10 days, and 40% activity level over the remaining 40 days.

This seemed to be a good scheme and I thanked Pat for his detailed input throughout the project.

Person Contacting: Venus Sadeghi, URS Corp.

Telephone Call Record

Person Contacted: Phillip Camp, Arizona Department of Agriculture
Telephone: (602) 280-8837
Date of Contact: 9/25/00
Subject: Silt Content of Agricultural Land in Maricopa County

Summary

I described to Phil how I used the SSURGO tables to calculate the silt content of agricultural land in Maricopa County. I asked his opinion on whether the resulting 31.7% silt content seemed reasonable.

Phil cautioned me that a "primfml" code of zero did not necessarily indicate that a map component was not used for agricultural purposes. He suggested that the use of maps would be preferable.

I agreed that use of maps would be a better approach but that in view of the lack of time, apportionment of farmlands by using maps and subsequent reconciliation with the SSURGO tables would not be feasible.

Phil mentioned that without seeing the data, he could not give me an opinion on the plausibility of my estimated silt content.

But he graciously agreed to review the silt content assignments by soil texture.

I proceeded to fax these assignment to Phil (fax: 602-280-8805).

Person Contacting: Venus Sadeghi, URS Corp.

Telephone Call Record

Person Contacted: Dr. Phillip DeNee, Arizona Department of Environmental Quality
Telephone: (602) 207-2355
Date of Contact: 9/22/00
Subject: Use of an Annual Climatic Factor to Calculate the Daily Emissions from Wind Erosion

Summary

I asked Phil to clarify the methodology used in the microscale inventory, regarding the above subject matter.

Phil explained that based on wind tunnel tests and other observations, it was shown that wind speeds greater than 15 miles per hour contributed to wind erosion. Therefore, the estimated annual PM10 emissions could be divided by the number of hours with wind speed greater than 15 miles per hour to obtain hourly emissions.

Person Contacting: Venus Sadeghi, URS Corp.

Telephone Call Record

Person Contacted: Stephen Francis, California Air Resources Board (ARB)
Telephone: (916) 322-6024
Date of Contact: 9/20/00
Subject: ARB=s Approach to Estimating PM10 Emissions from Windblown Dust from Agricultural Lands

Summary

I asked Steve to elaborate on ARB=s use of a revised wind erosion equation. How did they take the effects of irrigation and cloddiness into account?

Steve cautioned me that ARB=s approach to estimating the subject emissions was very data and time intensive. For example, and to name a few, detailed data on pre- and post-harvest crop canopy, bare and border segments, wind energy profiles and climatic data, frequency of irrigation, and the resulting soil wetness was needed to use the ARB=s revised equations. He advised me to review the A*Supplemental Documentation for Windblown Dust* B *Agricultural Land*@ (ARB, 1997). The detailed crop canopy and cloddiness factor data could reduce the emissions by 30%. The AC@ factor in the AP-42 wind erosion equation was developed based on data from Kansas. The effects of irrigation were not taken into account. These effects are different that precipitation effects. Irrigation causes soil crust formation and cloddiness. However, simply knowing the inches of water irrigated is not sufficient. Rather, the frequency of irrigation appears to be a more important factor. For monthly emissions, the ARB approach is to calculate the climatic factor based on a Amonth-as-a-year@ approach.

Rather than trying to use the ARB=s approach to calculate PM10 emissions for Maricopa County, Steve suggested that in view of the short amount of time available, a better approach may be to do the following:

$ Review and compare the Aerosive wind energy@ for San Joaquin County to that for Maricopa County (he also mentioned California=s Imperial County B which has monsoon type weather - as another possible candidate);
$ Compare the Aprecipitation regime@ in the month of April between the counties;
$ Compare the mix of vegetables between the counties;
$ Compare the irrigation practices between the counties; and
$ Compare the soil types between the counties.

Then, if the comparisons are favorable, select the same climatic, cloddiness, and plant canopy factors as the county(s) most similar to Maricopa county.

I mentioned that a climatic factor for Maricopa county was already available from the microscale PM10 emission inventory. Upon hearing this, Steve suggested that we use this factor to get the annual emissions and then to use the wind data to scale down to monthly and/or daily emissions. (We agreed, however, that use of the ARB approach would be more appropriate if more time were available in the future.)
Person Contacting: Venus Sadeghi, URS Corp.